Examining the Temporal Variability of Ammonia and Nitric Oxide Emissions from Agricultural Processes

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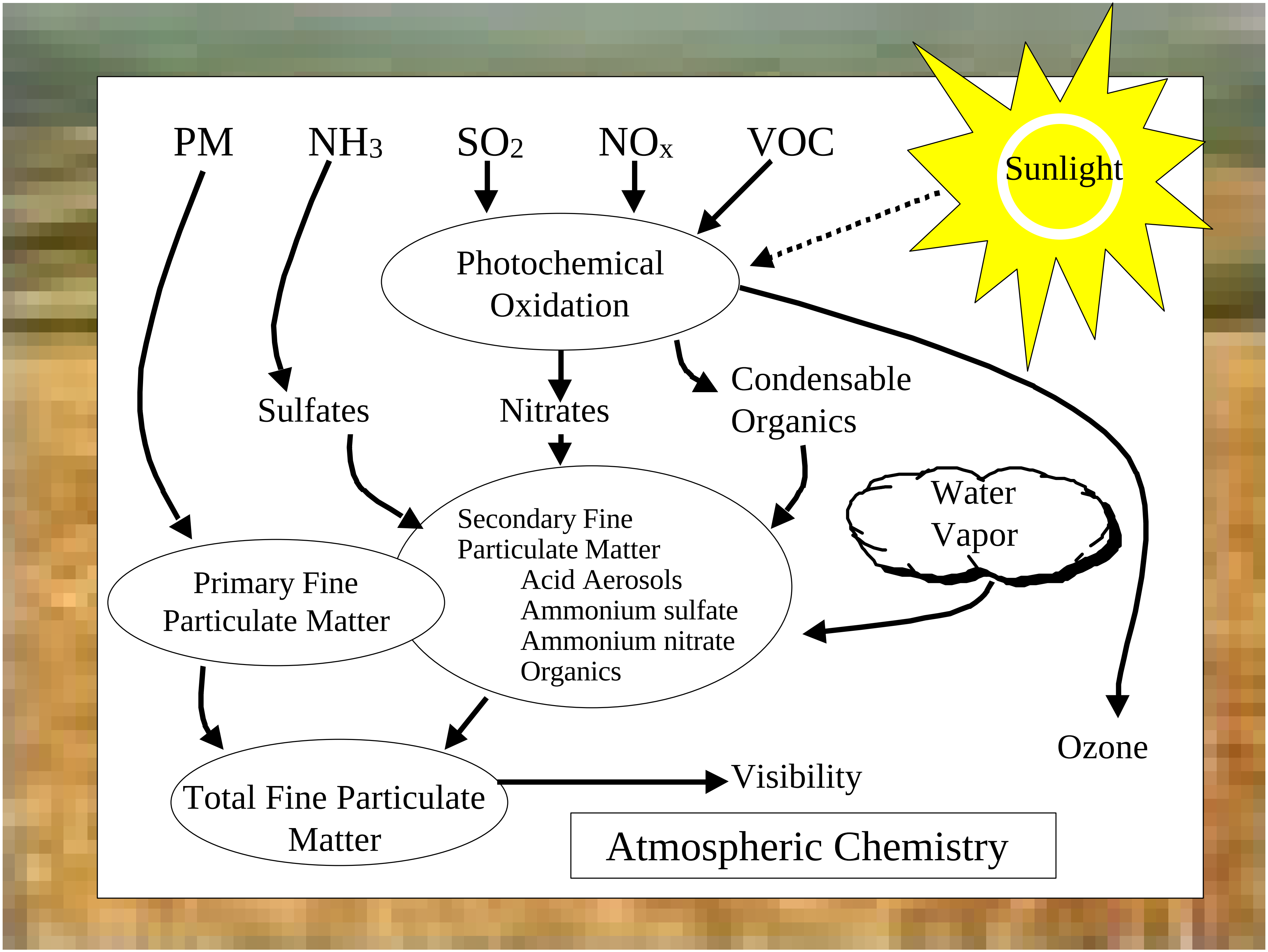
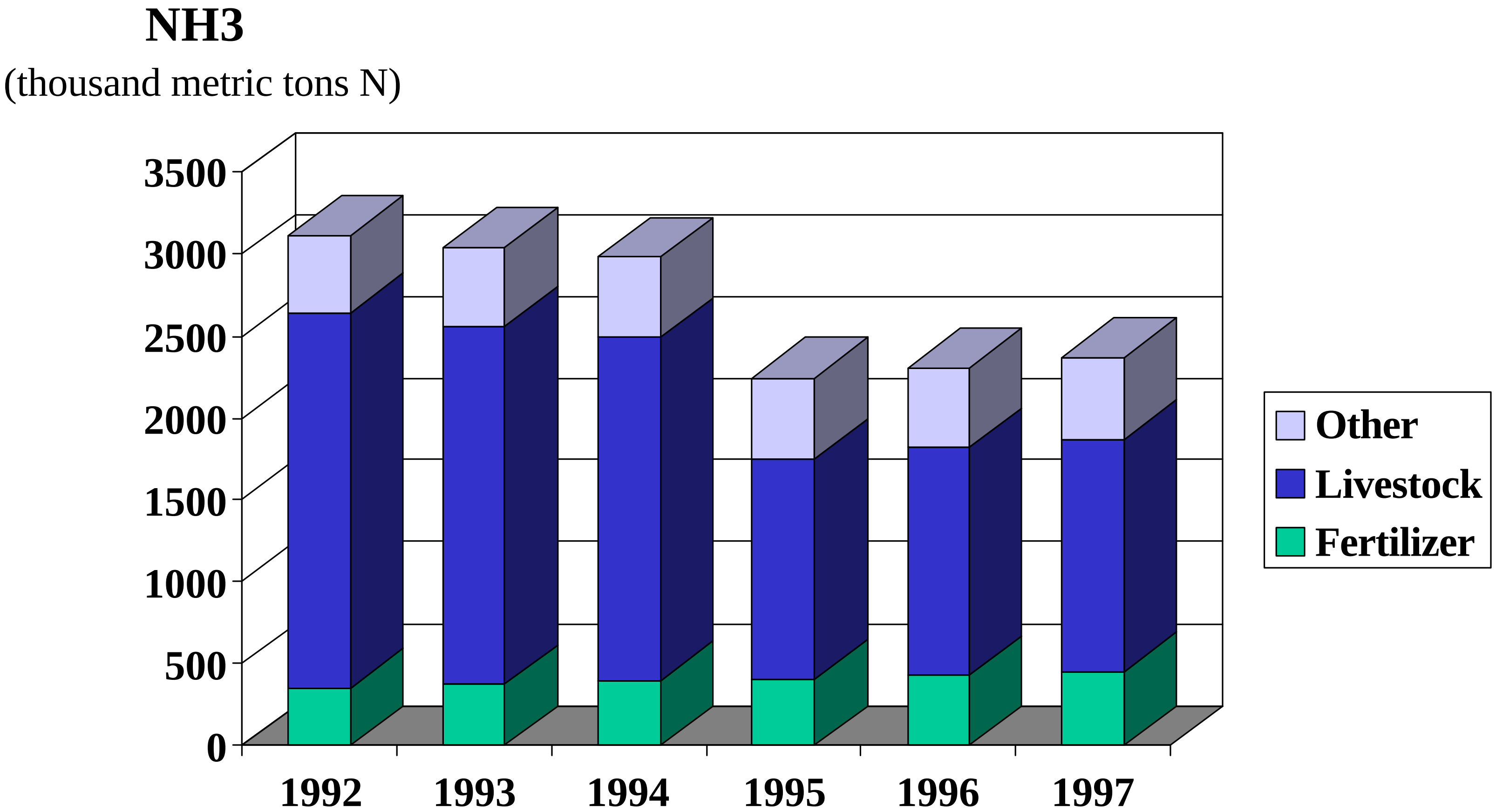


PM
NH3
SO2
NOx
VOC
Sunlight
Photochemical Oxidation
Condensable Organics
Sulfates
Nitrates
Water Vapor
Secondary Fine Particulate Matter
Acid Aerosols
Ammonium sulfate
Ammonium nitrate
Organics
Primary Fine Particulate Matter
Ozone
Total Fine Particulate Matter
Visibility
Atmospheric Chemistry

1992 - 1997 Net Inventory



Source: EPA National Air Pollutant Emission Trends Update, 1970-1997 (1998)

Estimates of ammonia emissions from livestock for 1992

96.1 million cows x 22.9 kg NH_3/cow	2201 x 10^6 kg NH_3
57.6 million hogs x 9.2 kg NH_3/hog	530 x 10^6 kg NH_3
351.3 million layers-pullets x 0.18 kg NH_3/chicken	63 x 10^6 kg NH_3
835.2 million broilers x 0.18 kg NH_3/chicken	150 x 10^6 kg NH_3
87.6 million turkeys x 0.86 kg NH_3/turkey	75 x 10^6 kg NH_3
10.8 million sheep x 3.4 kg NH_3/sheep	37 x 10^6 kg NH_3
Total independent calculation:	3056 x 10^6 kg NH_3
1992 NET inventory (livestock):	2785 x 10^6 kg NH_3

Source of data: Agricultural statistics from the U.S. Department of Agriculture (http://www.nass.usda.gov/census/); emission factors from Batteye et al.; 1992 NET inventory from EPA (1998).

Estimates of ammonia emissions from livestock for 1997

99.0 million cows x 22.9 kg NH_3/cow	2267 x 10^6 kg NH_3
61.2 million hogs x 9.2 kg NH_3/hog	563 x 10^6 kg NH_3
367.0 million layers-pullets x 0.18 kg NH_3/chicken	66 x 10^6 kg NH_3
1037.2 million broilers x 0.18 kg NH_3/chicken	187 x 10^6 kg NH_3
104.3 million turkeys x 0.86 kg NH_3/turkey	90 x 10^6 kg NH_3
7.8 million sheep x 3.4 kg NH_3/sheep	27 x 10^6 kg NH_3
Total independent calculation:	3200 x 10^6 kg NH_3
1997 NET inventory (livestock):	1715 x 10^6 kg NH_3

Source of data: Agricultural statistics from the U.S. Department of Agriculture (http://www.nass.usda.gov/census/); emission factors from Batteye et al.; 1997 NET inventory from EPA (1998).

Recommendations for the NET Inventory

Based on a review of livestock emissions from the 1992 – 1997 inventory:

(1) Inventories should use the latest available (or if necessary, projected) animal population statistics.

(2) Inventories should include a turkey category.

(3) Inventories should account for the <u>total</u> chicken population, by including layers/pullets—called "all chickens" by the USDA—and commercial broilers.

(Note: These recommendations have been considered in the 1998 NET inventory.)

Nitrogen-based fertilizer usage in the United States

Crop	Fertilized area (10^6 ha)	Typical fertilizer application rate (kg N/ha)	Total fertilizer (10^6 kg N)	Fertilizer (percent of total)
Corn	28.26	141	3985	63%
Wheat	23.81	63	1500	24%
Cotton	5.34	93	497	8%
Soybeans	2.68	6	16	2%
Miscellaneous	1.54	141	217	3%

Source: U.S. Department of Agriculture (1996) Agricultural Chemical Usage, 1995 Field Crops Survey, National Agricultural Statistics Service, Washington DC (http://usda.mannlib.cornell.edu)

Proposed Seasonal Allocations of Ammonia Emissions from Fertilizer Application

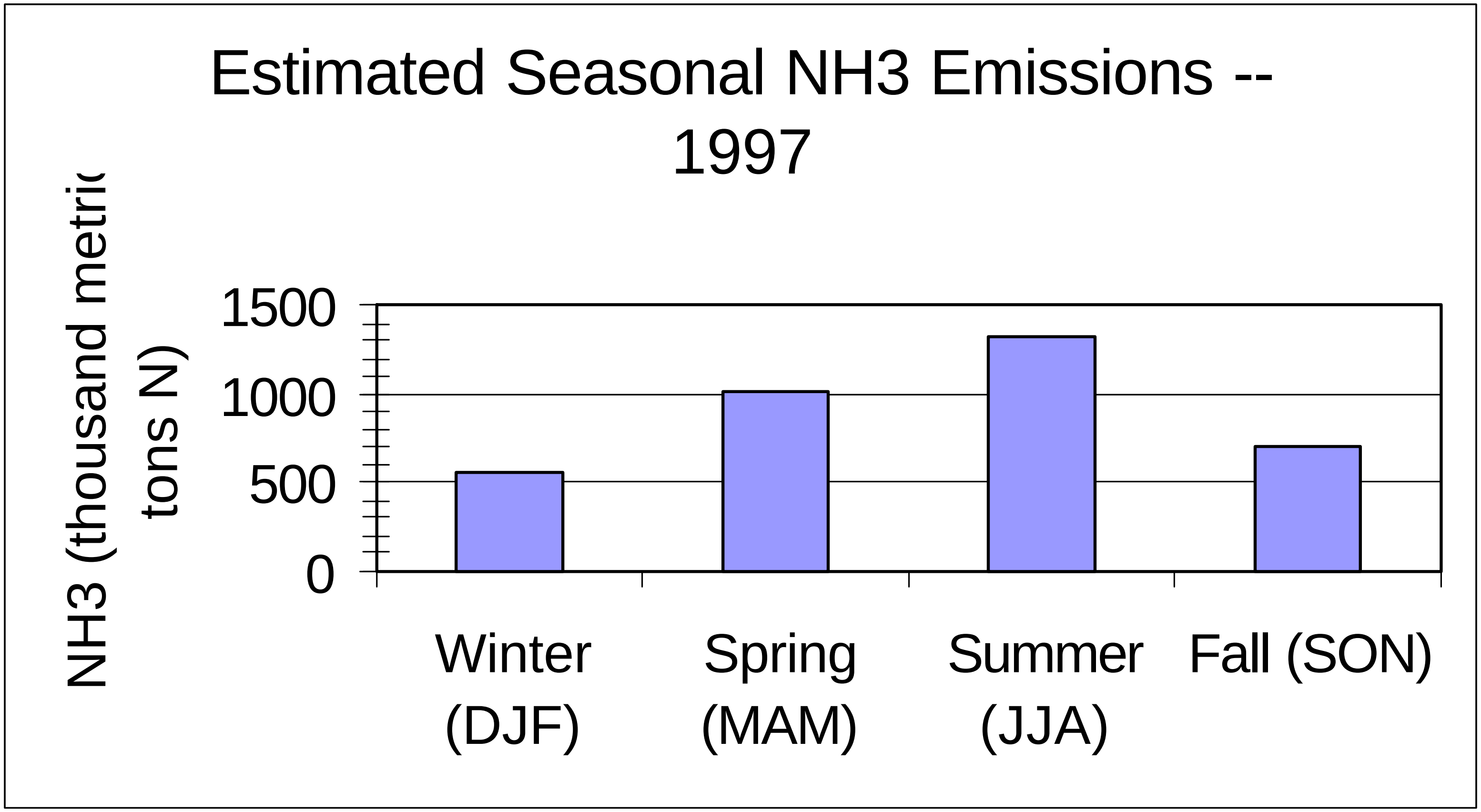
Season	Allocation
Winter (DJF)	10%
Spring (MAM)	50%
Summer (JJA)	30%
Autumn (SON)	10%

Tentative Seasonal Allocations of Ammonia Emissions from Animal Husbandry

Season	Allocation
Winter (DJF)	15%
Spring (MAM)	25%
Summer (JJA)	40%
Autumn (SON)	20%

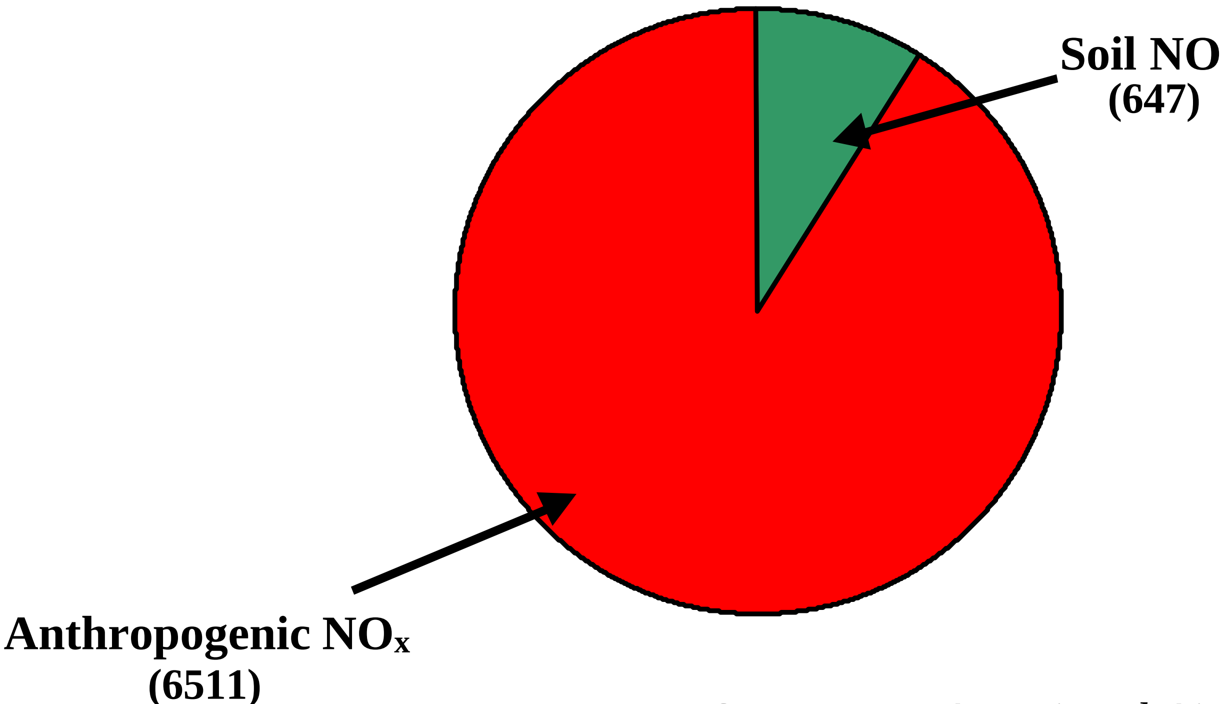
Rationale (based mostly on European studies):

(1) Assume that emissions from animal houses do not vary seasonally (questionable assumption).
(2) Emissions from houses contribute up to 50% of the total inventory.
(3) Emissions increase when "slurry" is applied to fields, which tends to occur during the growing season.
(4) Volatilization rates increase during warm/dry conditions (~50%/10 C temperature increase).



Estimated Seasonal NH3 Emissions -- 1997
NH3 (thousand metric tons N)
1500
1000
500
0
Winter (DJF)
Spring (MAM)
Summer (JJA)
Fall (SON)

NO_x Emissions for 1997 (thousand metric tons N)



Source: EPA National Air Pollutant Emission Trends Update, 1970-1997 (1998)

Environmental Algorithms for Soil NO Emissions

Existing BEIS2 algorithm:

$$E_T = E_{30} \times \exp[0.071 \times (T - T_s)]$$

E_T = NO emission flux at soil temperature T (C),
E_{30} = normalized emission flux at soil temperature 30 C,
T_s = standardized soil temperature (30 C)

Proposed new algorithm (Yienger and Levy, Empirical model of global soil-biogenic NOx emissions, *JGR*, **97**, 7511-7519, 1995)**:**

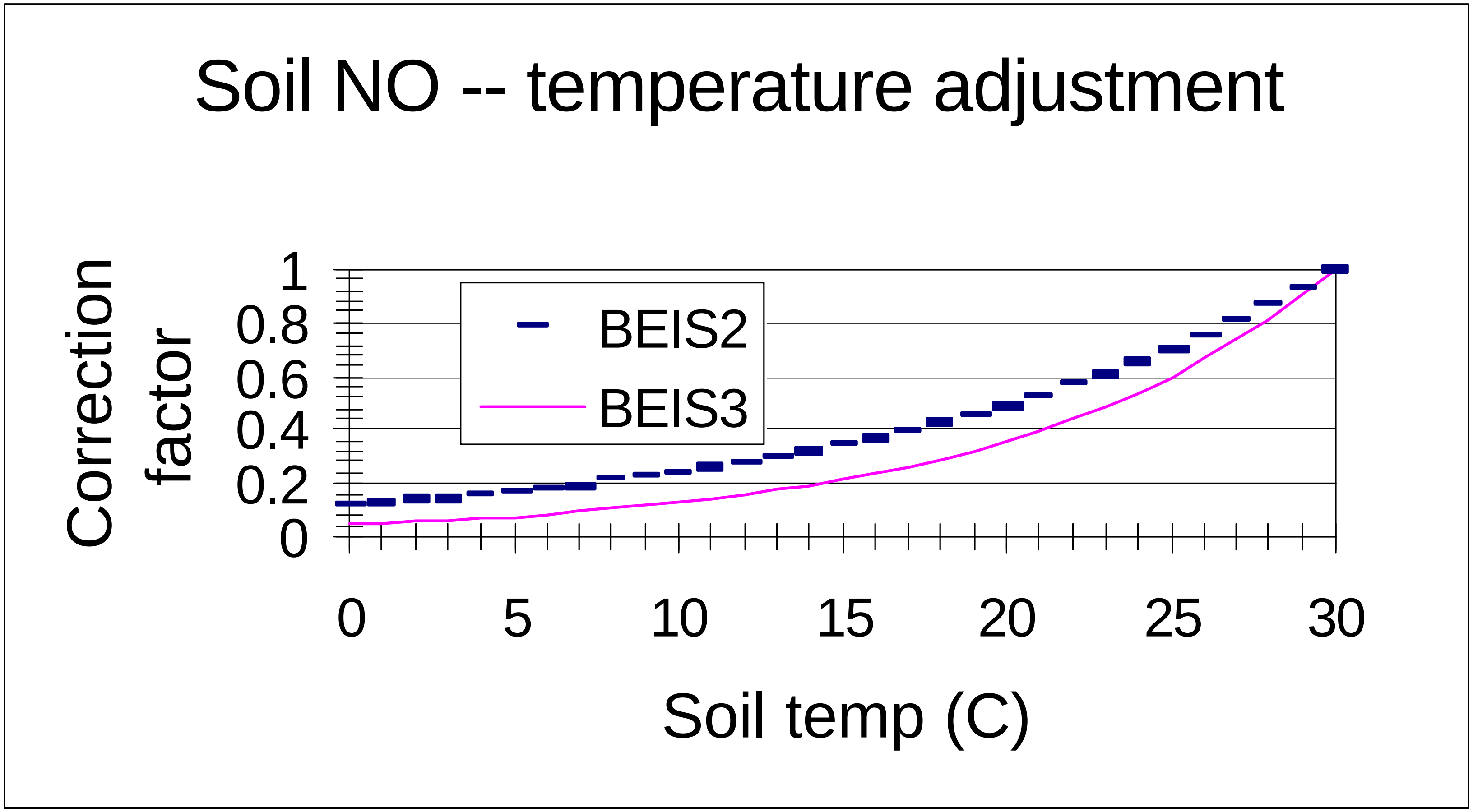
$$E = R_{2.5} \times T_{adj} \times P_{adj} \times F_{adj} \times C_{adj}$$

E = NO emission flux corrected for environmental conditions,
$R_{2.5}$ = normalized flux assuming that 2.5% fertilizer nitrogen is emitted as NO during the growing season,
T_{adj} = temperature adjustment factor,
P_{adj} = precipitation adjustment factor (1-15),
F_{adj} = fertilizer adjustment factor (0-1),
C_{adj} = canopy adjustment factor (0.5-1)

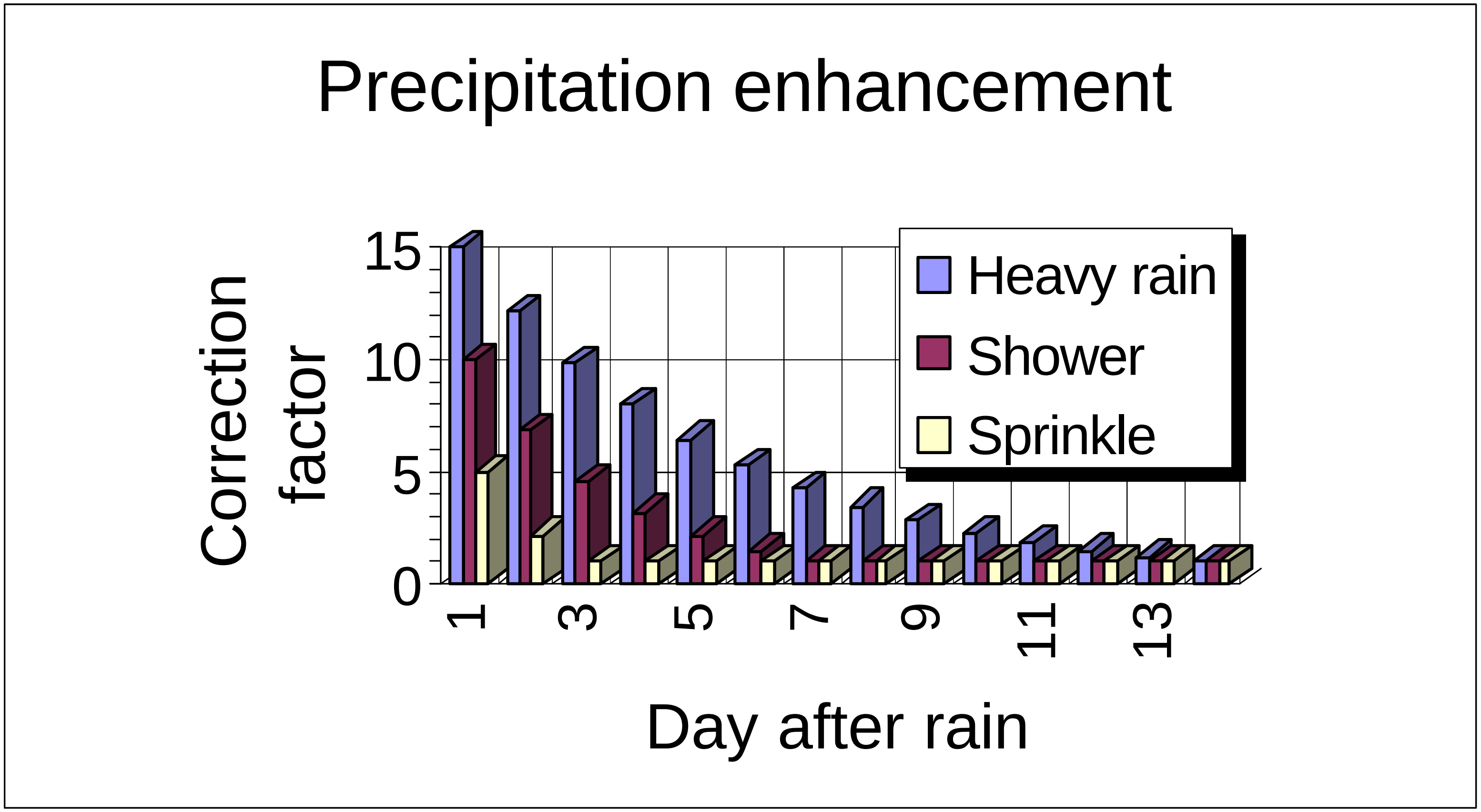
Normalized Soil NO Emission Rates

Crop	BEIS3 factor (μg NO m^{-2} h^{-1})	BEIS2 factor (μg NO m^{-2} h^{-1})
Potatoes	258	193
Corn	145	578
Sorghum	145	578
Barley	97	257
Cotton	97	257
Oats	97	257
Tobacco	97	257
Miscellaneous	85	13
Wheat	65	193
Alfalfa	58	13
Hay	58	13
Pasture	58	58
Peanuts	58	13
Rye	58	13
Soybeans	58	13
Rice	1	1

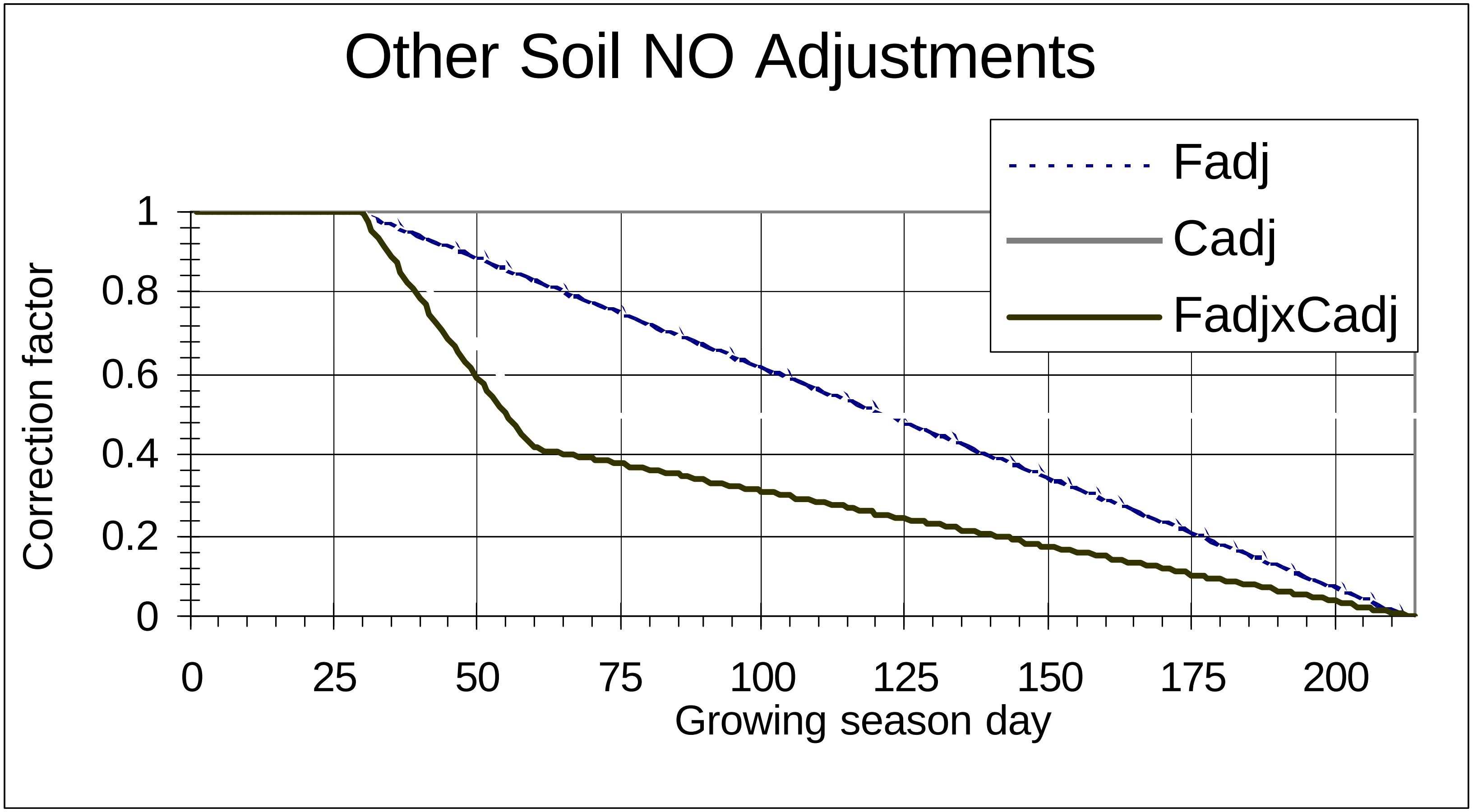
(1) BEIS3 factors are based on a loss rate of 2.5% from nitrogen fertilizer and a growing season of 214 days.
(2) Miscellaneous rate based on average fertilizer application of all other crops.



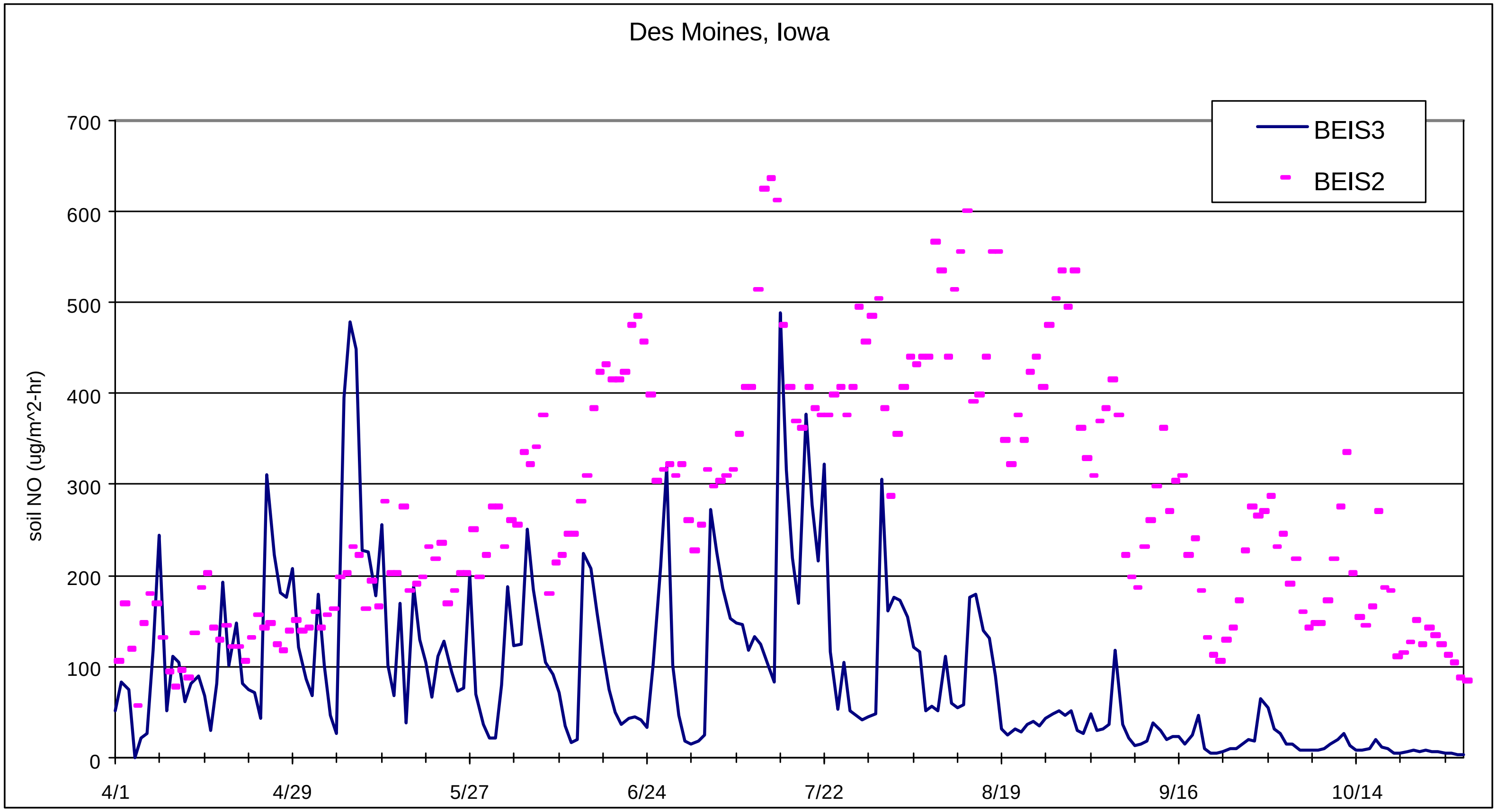
Soil NO -- temperature adjustment
Correction factor
1
0.8
0.6
0.4
0.2
0
BEIS2
BEIS3
0
5
10
15
20
25
30
Soil temp (C)



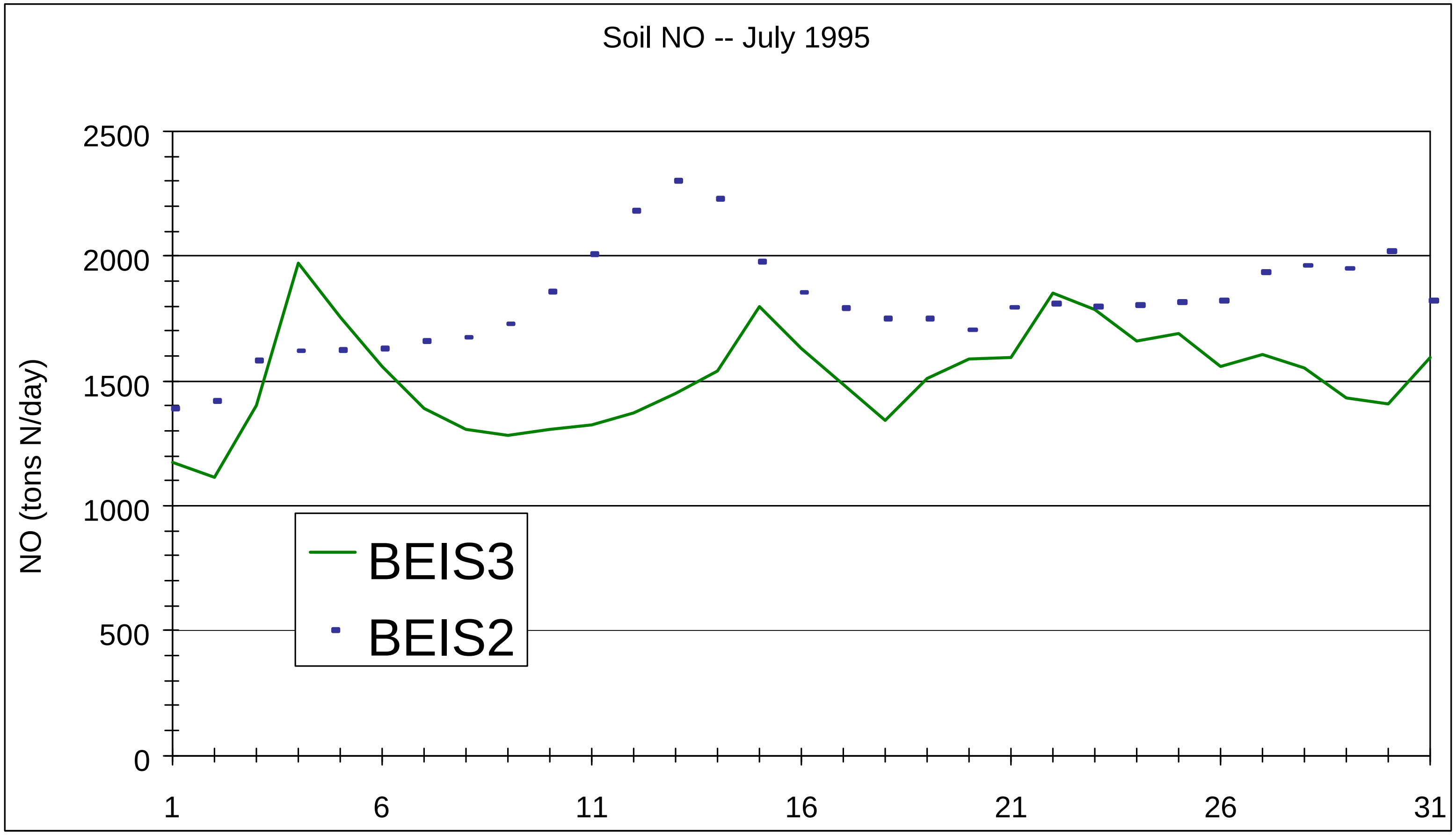
Precipitation enhancement
Correction factor
0
5
10
15
1
3
5
7
9
11
13
Day after rain
Heavy rain
Shower
Sprinkle


Other Soil NO Adjustments
Fadj
Cadj
FadjxCadj
Correction factor
1
0.8
0.6
0.4
0.2
0
0
25
50
75
100
125
150
175
200
Growing season day

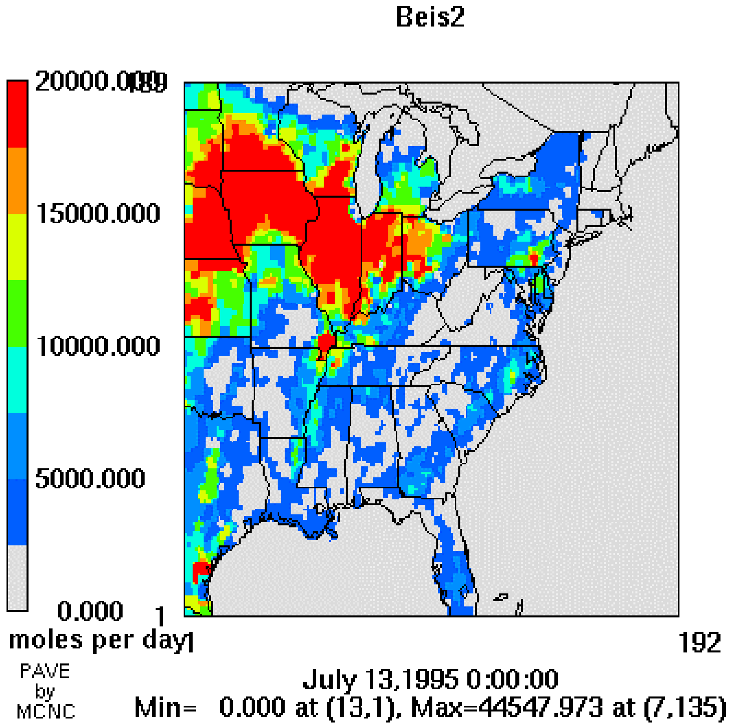
Daily average fluxes for corn using 1995 DSM met data

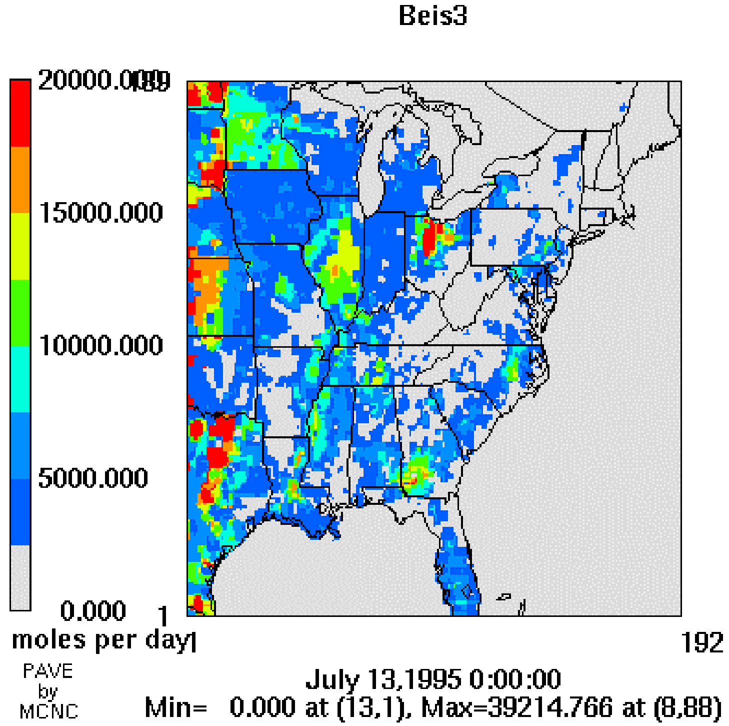


Simulation for the UAM eastern U.S. modeling domain using meteorological data from July 1995

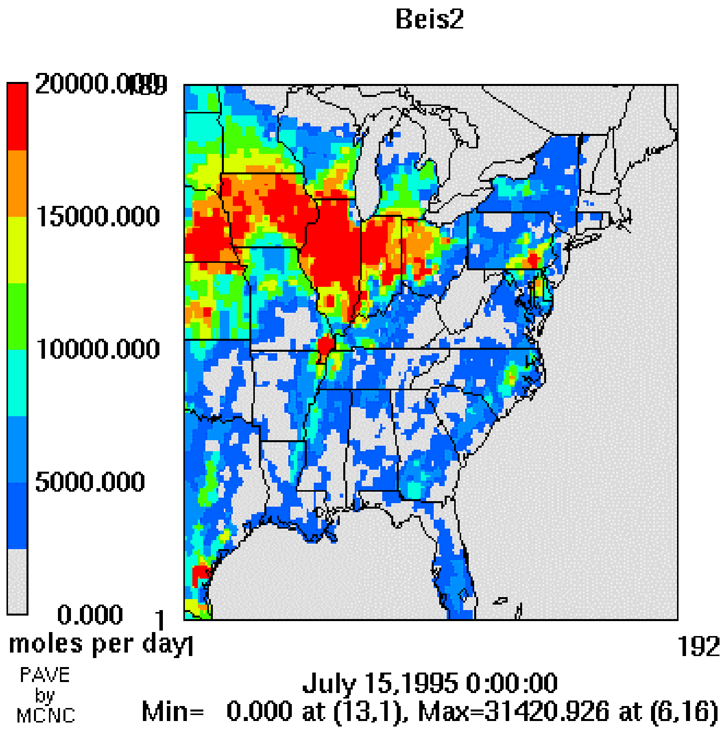


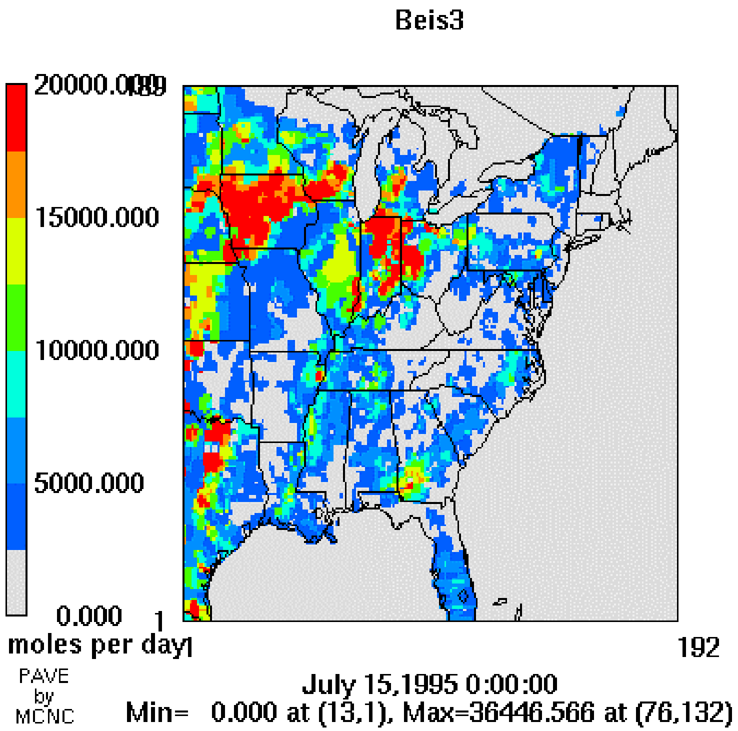
Layer 1 no


Beis2
20000.000
189
15000.000
10000.000
5000.000
0.000
1
moles per day
1
192
PAVE
by
MCNC
July 13,1995 0:00:00
Min= 0.000 at (13,1), Max=44547.973 at (7,135)


Beis3
20000.000
189
15000.000
10000.000
5000.000
0.000
1
moles per day
1
192
PAVE
by
MCNC
July 13,1995 0:00:00
Min= 0.000 at (13,1), Max=39214.766 at (8,88)

Layer 1 no


Beis2
20000.000
189
15000.000
10000.000
5000.000
0.000
1
moles per day
1
192
PAVE
by
MCNC
July 15,1995 0:00:00
Min= 0.000 at (13,1), Max=31420.926 at (6,16)


Beis3
20000.000
189
15000.000
10000.000
5000.000
0.000
1
moles per day
1
192
PAVE
by
MCNC
July 15,1995 0:00:00
Min= 0.000 at (13,1), Max=36446.566 at (76,132)

Summary and Recommendations

Ammonia:

- ⇨ crude seasonal adjustments of agriculture may change emissions x2
- ⇨ livestock adjustment is very tenuous

NEED: fertilizer application schedules and staged livestock measurements in the U.S.

Soil NO:

- ⇨ new (BEIS3?) algorithm yields more variability and overall lower emissions than BEIS2
- ⇨ algorithm will be more complex to implement

NEED: field verification